21. *On the* Occurrence *of* Pebbles *with* Upper Ludlow Fossils *in the* Lower Carboniferous Conglomerates *of* North Wales.

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Nearly forty years ago Mr. Bowman drew attention to "a small patch of Silurians west of Abergele." in which he described the following subdivisions in descending order*:—

f. A conglomerate of pebbles of greenish micaceous sandstone in a light loamy earth resting on a similar sandstone.
e. Thick red marl with numerous pebbles of red sandstone, micaceous, with many bivalves.
d. A hard compact conglomerate of green sandstone and quartzose rock.
c. Compact red limestone.
b. Fine blue loamy clay.
a. Clay-slate.

He makes the observation that the red-sandstone pebbles in bed *e* resemble Ludlow rock, and names four Ludlow species as occurring in them.

Our attention was directed to these beds by numerous excavations made in them at the time of the recent activity in the iron trade. The only good exposure is in Ffernant Dingle, a deep ravine running from the Pen-y-Cefn lane southward past Cefn-y-Fran, about one mile south of Llysfaen.

The southern or lower end of this dingle is occupied by Wenlock shale, a pale blue slaty clay, with occasional sandy beds. The beds are much jointed, and sometimes cleaved so as to weather into pencil-like fragments. At the south end of the dingle they are nearly horizontal, but dip gently to the north higher up, near Cefn-y-Fran.

At this point the Wenlock shale is unconformably overlain by hard, mottled, red and green brecciated limestone, containing beds of green sandstone pebbles in a sandy matrix. The limestone and the conglomerates dip to the N.N.E. at 28°.

This limestone constitutes bed *c* of Mr. Bowman's section. It is exceedingly hard, with a hackly fracture, of a green colour mottled with red. It contains perfectly angular fragments of Wenlock shale, and rounded pebbles of a greenish sandstone; there is also so large a proportion of quartzose and argillaceous impurity in it as to give

* Geological Transactions, vol. vi. part 1.

rise to a porous sandy mass when the lime is removed by weathering. We have been unable to detect any organic remains in it, even with the aid of the microscope. In all these respects it contrasts with the Carboniferous Limestone proper, which is free from grit, and is almost entirely made up of fragments of Corals, Encrinites, and Foraminifera. This brecciated limestone is locally known as the Bastard Limestone.

The unconformable position of the Bastard Limestone on the Wenlock shale is shown in a quarry on the west side of the dingle, and in a pit 150 yards further to the west. The shale dips to the north at from 6° to 7°. Its bedding planes are cut off towards the north by the Bastard Limestone, which dips to the N.N.E. at from 26° to 27°. A little local breccia, consisting of small fragments of Wenlock shale in a red clay or brown earth, about from 8 to 12 inches thick, separates the limestone from the surface of the Wenlock shale. The limestone is also exposed south-east of Twynan-uchaf and near Tyn-y-Pistyll, and has been proved in hæmatite trials near Orsedd, and in the slope of the hill below Cefn-uchaf and Cefn-y-Castell. It is represented at the Pile House, near Colwyn, by a porous sandy bed, slightly calcareous, but in a much weathered condition. The Bastard Limestone occupies a position at the base of the beds about to be described over a considerable area.

A great thickness of shales, sandstones, and conglomerates overlies the limestone. The following details of the lower portion of these beds were obtained in Ffernant Dingle, in ascending order:—

Section from Ffernant Dingle to the Carboniferous Limestone near Isallt. (Scale 6 inches to one mile.)

a. Wenlock shale. *b.* Bastard Limestone. *c.* Shales, sandstones, and conglomerates. *d.* Conglomerates and shales. *e.* Carboniferous Limestone.

	ft.	in.
Bastard Limestone, containing two beds of green sandstone pebbles in a sandy matrix	10	0
Conglomerate of red and green sandstone pebbles in a mottled red and green sandy matrix, the pebbles varying in size from that of a walnut to that of a flattened cricket-ball	12	0
Bastard Limestone	1	6
Fine gravel	0	8
Red shale	3	0
Bastard Limestone	1	0
Hard red sandstone crammed with green and red sandstone pebbles	3	0
Bastard Limestone	1	0
Soft, red, micaceous sandstone with pebbles	6	0
Thick deep-red clay, crammed with liver-coloured sandstone pebbles, micaceous, flattish, and fissile, the largest 1 foot across by 2 or 3 inches thick	20	0
Soft red sandstone with green blotches	3	0
Deep-red marl, weathering into cubes or rhombs (resembling some beds at the base of the Keuper marls of Cheshire)	3	0
Coarse conglomerate of purple sandstone pebbles	6	0
Soft bright-red sandstone	10	0
Thick deep-red clay, crammed with pebbles (bed *e* of Mr. Bowman)		

The last-named bed, with a few sandstones, occupies the remainder of the dingle, and continues over Pen-y-Cefn and down the slope to the north to near the foot of the limestone escarpment, a distance of more than 1000 yards; its thickness must therefore be very great. It is everywhere crowded with pebbles of red and purple sandstone, liver-coloured when fine-grained, and purple and very micaceous when coarse-grained. They are all fissile, and when split open disclose casts of numerous fossils. They vary in size from 14 inches $\times$ 8 inches $\times$ $3\frac{1}{2}$ inches to an average of 4 inches $\times$ $2\frac{1}{2}$ inches $\times$ $1\frac{1}{2}$ inch. They are dissimilar to any rock known *in situ* in the district, and are invariably waterworn, generally to a flattened oval shape, but occasionally subangular. The whole deposit is well stratified and pervaded by current-bedding, without any appearance of ice-action. Throughout this vast mass of pebbles there is no other rock than the fine and coarse-grained red sandstone.

Overlying this thick bed, and occupying the slopes immediately under the Carboniferous Limestone, are some conglomerates of green and yellow sandstone pebbles in a red and green matrix, and associated with mottled red and green shales. Some of the pebbles differ slightly from the last described in being tougher and less fissile, but the majority are similar except in colour; they also contain the same fossils. No hard and fast line can be drawn separating the red conglomerates of Ffernant from these mottled beds; and the difference is probably due partly to their having been derived from a variegated rock, partly to subsequent alteration. Some of the pebbles in the upper beds are partly green and partly red.

The red and green shales and conglomerates are succeeded by the Carboniferous Limestone, the lowest beds of which contain Encrinites, *Producti*, *Athyris*, and Foraminifera in abundance. The junction is visible in a farmyard near Bryniau Cochion, where red-

stained limestone, rather impure, rests on green and purple shales, with a sharp line of demarcation, but without signs of erosion or unconformity. Occasionally the lower beds of the limestone are interstratified with shales so as to form a passage*. There is always a perfect conformity in dip.

Distribution and Thickness.—The accompanying section (p. 269) is drawn to a true scale of 6 inches to the mile, the horizontal distances and heights taken from the Ordnance 25-inch maps, supplemented by aneroid measurements. The dip of the Bastard Limestone in the dingle is 28°; this diminishes towards the top of the dingle to 12°. No dip is then to be got till we reach the Carboniferous Limestone, which dips at 9° to 10°. From these data we get an apparent thickness of a thousand feet for the conglomerates. It is probable that this far exceeds the reality, through the inequality of the surface of Wenlock shale and through the possibility of a roll in the limestone. Making allowance for this, their thickness cannot be much less than 500 feet. At Penlwys (Pile House), where we have been able to make a direct measurement in the hill-side, we find the thickness to be 130 feet, and west of Colwyn Bay they have thinned out to nothing, the rate of attenuation being about 1 in 34. Eastwards the conglomerates thin out equally rapidly, and finally are overlapped by the Carboniferous Limestone at a distance of three miles from Ffernant. The conglomerates become finer as the beds become thinner, and tend to pass into shales and sandstones, affording evidence that the thinning and thickening of the beds is due to their original unequal distribution, rather than to their partial removal by denudation before the deposition of the Carboniferous Limestone.

The position and appearance of the beds in Ffernant Dingle favour the idea of their having been deposited against a bank or sloping surface of Wenlock shale, probably one side of a broad hollow cut out by denudation in the surface of these rocks. The irregular distribution of the conglomerates is probably due to such inequalities in the surface on which they were deposited.

It may be mentioned that a fine section is exposed in the valley of the Clwydog, near Ruthin, showing Carboniferous Limestone resting conformably on red micaceous shales with thin sandy beds, and thrown against similar beds by a fault ranging north and south through Berth. In the bed of the river at Berth brecciated and conglomeratic limestone, dipping N.E. at 5°, forms the base of the deposit; it rests on Wenlock shale dipping S.W. at 30°. Conglomeratic beds occur in the series in the side of the highroad to Ruthin, half a mile west of Llantwrog. The pebbles are similar to those of Ffernant.

Origin of the Pebbles.—In the Bastard Limestone there occur a few fragments of Wenlock shale, all angular and evidently of local origin. With the exception of these, the pebbles are all waterworn and generally completely rounded. A few of the less fissile and

* Mr. G. H. Morton states that beds of limestone and conglomerate are interstratified near Denbigh.

finest-grained green pebbles from the upper part of the conglomerates resemble the sandy beds in the Wenlock shale, but the vast majority are totally dissimilar to any rock known *in situ* in the district. On the other hand, they closely resemble the Upper Ludlow beds of Kendal and Central Wales, both the red and green varieties being referable to these beds*.

Mr. R. Etheridge has kindly examined some of the pebbles, and has named the following genera and species of fossils occurring in them:—

Orthis filosa, *Sow.*, *Sil.* xx. 21. Wenlock and Ludlow.
—— lunata, *Sow.*, *Sil.* xx. 11. Ludlow.
—— elegantula, *Dalm.* Llandeilo to Ludlow.
—— crispa, *M'Coy*, *Sil. Foss.* p. 29. Llandeilo to Ludlow.
Chonetes striatella=lata, *Dalm.*, *Sil. Syst.* iii. Ludlow. Four specimens.
Spirifer crispus, *His.*, *Sil.* xxi. 4. Llandovery to Ludlow. Five specimens.
—— elevatus, *Dalm.*, *Sil.* xxi. 5, 6. Llandovery to Ludlow.
Rhynchonella Stricklandii, *Sow.*?, or borealis, *Schl.* Wenlock.
—— ——: fragments.
Pterinea retroflexa, *Wahl*, or lineata, *Goldf.*, *Sil.* ix. 26. Ludlow. Three specimens.
Orthonotus.
Arca (or Pterinea?).
Theca (?).
Tentaculites ornatus, *Sow.*, *Sil.* xxvi. 11. Caradoc to Wenlock.
Holopella.

He remarks that they are undoubtedly Upper Silurian and 90 per cent. Ludlow, and that the pebbles in their flaggy nature and micaceous condition resemble beds of this age in Westmoreland.

In considering from what direction the pebbles have been transported it is necessary to bear in mind that, excepting only the angular fragments in the Bastard Limestone at the base, not a single fragment occurs that is referable to the Wenlock, or any Silurian rock older than the Wenlock. It is therefore certain that the denudation in that area from which the conglomerates were derived had not been sufficient to remove the whole of the Ludlow beds and expose the underlying Wenlock shales, fragments of which must otherwise have occurred in the conglomerates. We must therefore look for the source of the pebbles in an area in which the Silurian series remained perfect, at least so far as the Lower Ludlow beds, when the pre-Carboniferous denudation of these rocks ceased.

This condition is fulfilled at Ludlow, at a distance of more than fifty miles to the south. But over this intervening space the Carboniferous Limestone is resting on Wenlock shale, which was therefore undergoing denudation and contributing débris. Had the drift been from this direction, this Wenlock débris must have been intermingled. Similarly to the west, near Snowdon and Anglesey, and to the north-west, in the Isle of Man, the Carboniferous rest on Wenlock or older beds, so that these directions need not be discussed. There remains only to be considered the possibility of a source in a north or north-easterly direction.

The removal of the Ludlow beds from the areas of North Wales

* On this point we had the valuable opinion of Mr. W. T. Aveline, F.G.S.

and the Lake-district was due to the elevation of these tracts, and consequent denudation, in a period preceding the Carboniferous. The comparative depression of the intermediate area of South Westmoreland, and probably Lancashire, and of South Wales preserved these beds or a portion of them, or even led to further deposition, so that 10,000 feet of red beds are found in Herefordshire which are missing in Denbighshire. While in the areas of elevation the unconformity at the base of the Carboniferous is immense, in the areas of depression the gap is *apparently* filled up through the comparatively slight denudation to which the beds were exposed.

Neglecting minor undulations, the general tendency of the Wenlock shale of North Wales is to dip in a north-east direction off the Bala beds of Conway and Bala. If this dip is continued under the Carboniferous strata it must bring on in natural succession the missing Silurian beds in the direction of Liverpool and Lancashire. On the southern side of the Lake-district, where the Silurians reemerge, the series is actually complete as far as the Kendal Flags (Tilestones) before it is overlapped by the Carboniferous.

It is therefore probable that in the old synclinal between Wales and the Lake-district, Silurian beds higher than any existing in North Wales underlie the Carboniferous strata. The resemblance of the Ffernant pebbles to the Westmoreland beds has been remarked by Mr. Etheridge; but from the large size, incomplete rounding, and friable nature of some of the pebbles, it is not probable that they have travelled so far as from the Lake-district to Wales. We therefore suggest the probable extension of the Ludlow beds under Lancashire as the most likely source from which they can have been derived.

Mr. Goodchild has been kind enough to furnish us with the following notes on conglomerates occupying a similar position on the borders of the Lake-district. They rest with an extreme unconformity upon all the older rocks. On the other hand, they pass up into the limestone, or are sometimes rather sharply divided from it. They are also interstratified with beds of sandstone and even shale, which occasionally form the mass of the deposit. There is evidence in the conglomerates of their having been drifted from a north-west direction.

In the Isle of Man, near Castletown, the conglomerate rests on the smashed edges of nearly vertical Silurian strata. It is interstratified with discontinuous beds of sandstone and grit. In the upper part it is interbedded with Carboniferous Limestone. The Peel Sandstones are described by Mr. Horne* as containing occasional bands of breccia and thin cornstones, and as passing conformably under the limestone. In all cases the conglomerates are highly charged with iron.

Over a large area in the north and west of England and Wales these red conglomerate sandstones and shales are conformable to the Carboniferous Limestone, and occasionally interstratified with

* Trans. Edinburgh Geol. Soc. 1874.

it, while they invariably show the most complete unconformity with the Silurian beds below.

Discussion.

Mr. De Rance expressed his agreement with the paper after having walked over the ground. He also thought that the source of the pebbles had probably been the Lake-district or old destroyed lands under the Irish Sea. He had been informed by Mr. Morton that, in examining the caves in the Carboniferous Limestone near Abergele, east of the direction of the author's section, a number of these fragments had been found, showing underground drainage from the outcrop of the basement beds to the sea.

Prof. Hughes bore testimony to the accuracy of the observations of the authors, but thought caution was needed in accepting some of their conclusions. A bed might be stained in a conglomerate of a colour which it never bore *in situ*. Pebbles from grey rocks in the red basement conglomerates of the Carboniferous rocks in the Eden valley were stained red. He also thought that the general character of the pebbles did not agree with the Ludlow of the Lake-district. All the fossils were Ludlow, but also occurred low down in the Denbigh Flags.

Mr. A. O. Walker said that the conglomerates above these beds were of greenish or whitish pebbles, and so not in the least stained themselves. He thought that the pebbles in the caves mentioned by Mr. De Rance occurred in the drift.

Mr. Rutley said that an exposure of Upper Ludlow rock in the Long Sleddale valley of the Lake-district had a lithological character identical with that of the specimens brought by the authors.

The President asked if there was any physical evidence as to the direction whence the pebbles had drifted.

Mr. Strahan said that probably the hardest portions of the rock survived in the existing pebbles, which, however, were softer than the Wenlock shale. There was no other rock of similar character in the district. He also thought the general position of the beds favoured the idea of denudation they had suggested; but there was no certain physical evidence as to the direction whence the fragments had proceeded.